

# Using Nintendo Wii to improve Cognition in Traumatic Brain Injury

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## Abstract

The unfortunate accident of Michael Schumacher had highlighted the fact that Traumatic Brain Injury (TBI) can happen unexpectedly. Those who survive have to grapple with physical and cognitive disabilities. Hence it is important to investigate all possible treatment approaches to curtail TBI-related morbidity. This paper explores and evaluates the research evidence pertaining to treatment approaches relating to cognitive remediation and the use of electronic virtual reality. It describes a study whose objective was to identify improvement of cognition among Traumatic Brain Injury (TBI) patients by using Nintendo Wii Sports (NWS) as the intervention tool and to determine if months since injury, virtual reality experience and Glasgow Coma Scale affect Mini Mental State Examination Score after intervention. The experiment can be easily repeated in Neuro Clinics & Wards and Occupational Therapy Centres to test for improvements in cognition in the treatment of other ailments or injuries which have resulted in brain impairments. Thirty (30) Traumatic Brain Injury (TBI) patients with Mild Glasgow Coma scale (GCS) 33.3% (10) and Moderate Glasgow Coma scale (GCS) 66.7% (20) were selected. They were  $\geq 16$  years old and the number of months after injury was calculated at the time when GCS test was conducted. This is not to be confused with the work done at UCLA (Babikian et al., 2011) where the studies were on a sample of children with mild TBI. The number of months was longitudinal time points of the study. The main outcome measures used was the Mini Mental State Examination (MMSE). It was observed that there was significant improvement in cognitive functions from purposeful use of NWS. Even patients with moderate traumatic brain injury improved MMSE score after intervention. Mean MMSE result increased from 19.8 to 26.4. NWS intervention did show significant improvement in cognition among Traumatic Brain Injury patients with mild or moderate score of GCS independent of VR experience.

## Keywords

Nintendo Wii Game Sports (NWS), Glasgow Coma Scale (GCS), Mini Mental State Examination (MMSE), Traumatic Brain Injury (TBI)

## 1. Introduction

Virtual Reality (VR) systems provide stimulating and multidimensional environments in which real time body movement and object manipulation through virtual space are congruent with physical movement and object manipulation executed in the real world (Pessoa, et al., 2014 ; Wuang, et al., 2011 ; Sveistrup, 2004). VR in computer-simulated environments simulate physical presence, movements, actions and responses. For this reason, Nintendo Wii games (NW) have become popular human computer interaction tools for Occupational Therapy and Physiotherapy (Pessoa et al., 2014). They have been introduced in Malaysian hospitals to rehabilitate and to help in the recovery of patients with traumatic brain injury (TBI) since 2010. NW set is a video games system that requires patients to control the game by visually focusing on the TV and executing hand manipulation as well as body movement to enable the character in the game to move. Patients enjoy playing this game and have been observed to get immersed in game play. The game creates an environment during which patients are able to take their mind off the burden of the rehabilitation process. Patients are motivated to accomplish the goals of the game and are inspired to compete with other patients in the Occupational Therapy Department.

There are twenty one digital games in NW set from which Nintendo Wii Game Sports (NWS) was selected for this study as the intervention media. It is widely believed that involvement in NWS allows a TBI patient to strengthen various physical and cognitive functions such as concentration, memory, attention, and to some extent, problem solving. Many occupational therapists and physiotherapists have observed that TBI patients show improvements in upper limb coordination, visual perception, balance, cognitive ability and speech verbalization after a session of NWS. Although there is some evidence to show of the positive benefits of NWS among TBI patients, there has been no study to explore the cognitive effectiveness of NWS in neuro-rehabilitation specifically for Traumatic Brain Injury (TBI) patients.

## 2. Method

This paper aims at answering several questions which have been directed at Hospital Permai R&D regarding the use of VR games such as NWS to restore cognition of TBI patients. NWS is an inexpensive digital game which is played by the young and the old. It can provide an opportunity for patients to engage in more meaningful, age appropriate activities within a supported environment. For instance, participation in sports activities were shown to have decreased significantly following brain injury. NWS program will allow individuals to participate in an activity that simulates real – world activities (tennis, bowling, baseball, etc) in addition to providing an opportunity to potentially address physical and perceptual impairments during treatment. Behavioural disturbances and neuro cognitive deficits in attention, learning and memory commonly occur following TBI (Babikian et al., 2011). Cognitive function do empower patients with the cognitive and perceptual skills necessary to perform tasks or solve everyday problems (Intaité, et al., 2014 ; Diller & Gordon , 1981). TBI patients experience frustrating as well as difficult situations because many simple everyday tasks which were within their capabilities to perform before injury have become unsurmountable. Digitally simulated real life activities performed in a fun way do help TBI patients to improve problem solving, attention and memory. It was found that useful techniques to remediate inattention and visual spatial deficits can include the use of tracking tasks, cancelling tasks and training in the use of visual as well as proprioceptive cues (Ruitenber, et al., 2014 ; Jurko & Smith ; 1981) . Playing NWS with cues from the therapist may help TBI patients to improve their cognitive functions

### 2.1 Recruitment of subjects for the experiment

TBI patients were recruited from neuro-clinic, neuro-ward and out-patient centers of the Occupational Therapy Unit (OTU). Criterion sampling (non random) was carried out to provide exact representative subjects for the experiment. These subjects were tested and only those who were in the Inclusion criteria but who were outside the Exclusion criteria were selected. The flow chart of the selection procedure is as shown in Figure 1.

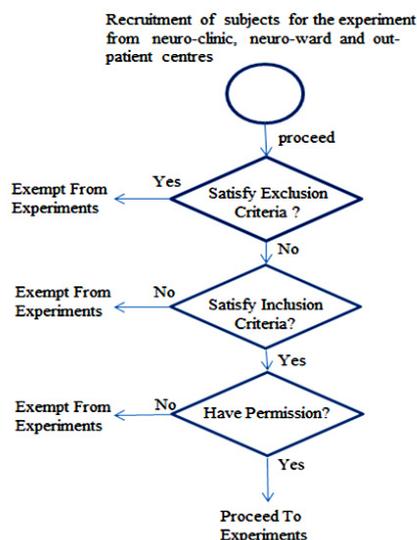


Figure 1. Flow Chart of the Selection Procedure to recruit Subjects for the Experiment

#### 2.1.1 The Inclusion criteria

1. TBI patients who scored Mild and Moderate in Glasgow Coma Scale
2. TBI patients who at least had movement both upper limb at shoulder, elbow and hand
3. TBI patient had no problem in vision and hearing
4. TBI patient who were free from pain upon movement

#### 2.1.2 The Exclusion criteria

1. TBI patients who scored Severe in Glasgow Coma Scale

#### 2.1.3 Study Protocol

It was compulsory to obtain informed consent and voluntary agreement from each TBI patient before any test or any experiment could be carried out. The date of any test or any experiment was selected based on the patient's free time.

## 2.2 Glasgow Coma Scale

Glasgow Coma Scale (GCS) is a well known measure to quantify the status of the nervous system with regards to the level of alertness or the level of consciousness which is associated with the level of injury a TBI patient is suffering from (Middleton, 2012 ; WomackArmyMedicalCenter, 2003; Teasdale, Knill-Jones, & van der Sande, 1978; Teasdale & Jennet, 1974). The measure takes into consideration aspects of the scale covering all the three tests on eye, verbal and motor responses according to Table 1. The sum from all these three readings provides the GCS score. The lowest possible GCS score is 3 (associated with deep coma or death), while the highest score is 15 (associated with being fully awake and conscious). TBI patients who's GCS score is  $13 \leq GCS \leq 15$  are considered to be suffering from mild injury while those who's GCS score is  $9 \leq GCS \leq 12$  are considered to be suffering from moderate injury.

**Table 1: Element of the Glasgow Coma Scale**

Glasgow Coma Scale						
Score	1	2	3	4	5	6
<b>Eyes</b>	Does not open eyes	Opens eyes in response to painful stimuli	Opens eyes in response to voice	Opens eyes spontaneously		
<b>Verbal</b>	Makes no sound	Incomprehensible sounds	Utters inappropriate words	Confused, disoriented	Oriented, converses normally	
<b>Motor</b>	Makes no movement	Extension to painful stimuli	Abnormal flexion to painful stimuli	Flexion / Withdrawal to painful stimuli	Localizes painful stimuli	Obeys commands

### 2.2.1 Best eye response (E)

The GCS score for eye responses starts with 1 which is associated with the most serious case when the patient's eyes do not open. GCS score = 2 if the patient opens the eyes in response to pressure on the fingernail bed or on the supra orbital and sternum or when a rub is applied. GCS score=3 if the patient opens the eyes in response to voice. This must not be confused with waking a sleeping patient by using voice call. In the case of awakening of a sleeping patient; a GCS score of 4 and not 3 should be given. GCS score=4 if the patient opens the eyes spontaneously.

### 2.2.2 Best verbal response (V)

GCS score = 1 if there is no verbal response. GCS score = 2 if the verbal response from the patient is not comprehensible e.g. moaning sound or voice response when no words are used. GCS score = 3 if the patient responds with random or exclamatory articulated speech without any conversational exchanges. GCS score = 4 if the patient responds to questions but there is some disorientation and confusion in the articulation. GCS score=5 if the patient behaves normally and responds coherently and appropriately to questions about the patient's name and age, where the patient think he is and why he is there , what day of month and what year etc.

### 2.2.3 Best motor response (M)

Best motor response of GCS is a good measure of the state of recovery of TBI patient (Jennett, 2005). With good recovery, bedside observation chart would normally show progressive improvement about every 2 days with regards to the best arm response. There are 6 scores for GCS best motor response, starting with the most severe, that is no motor response for which GCS score=1 is given (Regenbrecht et al., 2012). GCS score=2 if there is extension to painful stimuli which results in responses that include the abduction of the arm, internal rotation of the shoulder, the pronation of the forearm, extension of the wrist and abnormal posturing. GCS score=3, if there is abnormal flexion to pain such as the adduction of arm. GCS score=4 if the patient pulls part of body away when the nail-bed is pinched. When a patient is observed to execute purposeful movements towards painful stimuli, GCS score=5 is given. An example of purposeful movement is the action of the patient when he/she crosses his/her hand mid-line and moves it above the clavicle when supra-orbital pressure is applied. GCS score=6 if the patient makes simple movements when asked.

Generally, brain injury is classified as severe when  $GCS \leq 8$ , moderate when  $GCS$  is  $9 - 12$  and minor when  $GCS \geq 13$ .

## 2.3 Mini-Mental State Examination (MMSE)

The MMSE is used to screen for cognitive impairment and consist of 30 questions. It is also used to estimate the severity of cognitive impairment at a given point in time and to follow the course of cognitive changes in an individual over time (Folstein, Folstein, White, & Messer, 2014; Reisberg, Ferris, & Leon, 1982). In the time span of about 10 minutes it samples various functions including attention, memory, language and orientation. The MMSE test includes simple questions and problems in a number of areas: the time and place of the test, repeating lists of words, simple arithmetic, language use as well as comprehension, and basic motor skills.

Any score greater than or equal to 25 points (out of 30) is effectively normal (intact). Below this, scores can indicate severe ( $\leq 9$  points), moderate (10-20 points) or mild (21-24 points)(Folstein, Folstein, & McHugh, 1975).

## 2.4 Experimental Procedure

### 2.4.1 Intervention

The subjects of the experiment were requested to respond to questions on demographics and to proceed to MMSE. From this examination the MMSE score before intervention,  $MMSE_1$ , for each subject was recorded. Each subject was given a simple explanation about Nintendo Wii, after which he/she selected his/her favorite NWS category of sports game to play. Each game play session lasted for a maximum of one hour. The subjects (participants) were allowed to stop playing NWS if they felt uncomfortable, experienced dizziness or suffered light pain. After playing 2 sessions of NWS per week for 4 months (32 sessions altogether), each subject was made to undergo another reassessment of MMSE by the same initial therapist to obtain data for MMSE after intervention,  $MMSE_2$ . If a subject had mastered a NWS category of sports game, he/she was free to play another NWS category.

The flowchart depicting the intervention and assessment procedure is shown in Figure 2.

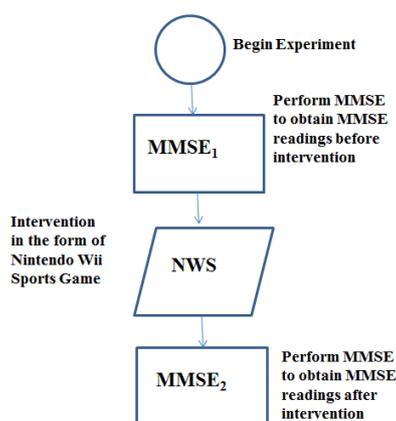


Figure 2. Intervention and Assessment Procedure

### 2.4.2 Nintendo Wii game– Sports (NWS)

NWS consisted of 5 NWS types of sports game which were tennis (NWS-Tennis), baseball (NWS-Baseball), bowling (NWS-Bowling), golf (NWS-Golf) and boxing (NWS-Boxing). All these types simulate situations which demand some efforts in problem solving, decision making, following instructions, attention and concentration. Several researchers believe that activities which strengthen patients' ability in frustration tolerance and skills coping stimulate patients' cognition (Regenbrecht et al.,2012 ; Serruya & Kahana, 2008 ; Castelnuovo, Priore, Liccione, Cioffi, Paolo, & Al, 2003)

#### 2.4.2.1 Tennis Game (NWS-Tennis)

A subject could choose to play NWS-Tennis individually or in pairs. There were three categories of NWS-Tennis, namely: single set game, 3 sets game and 5 sets game.

A subject would begin by playing a single set game. Assessment of endurance would be used to determine the subject's personal goals to gauge whether or not he/she could cope for game play in the next NWS-Tennis

category. Adjustments on the left justification, right justification and focus were needed to ensure that correct target hitting was synchronized to enable proper record keeping of points collected.

#### 2.4.2.2 Baseball Game (NWS-Baseball)

NWS-Baseball could be played by two opposing sides in a baseball field. For each team, the game consisted of nine inning scenes. In one inning, the offence side had a chance to hit the ball and run. In game play, subject used nun chuck to punch or throw the ball. Each team batted three times and fielded three times; and the team that scored the most number of runs was declared the winner.

#### 2.4.2.3 Bowling Game (NWS-Bowling)

For NWS-Bowling, subjects were required to complete ten games for each bowling session. Winning points depended on the total number of pin drops scored in each session.

#### 2.4.2.4 Golf Game (NWS-Golf)

There were 4 levels of game play in NWS-Golf; namely the beginner level, the intermediate level, the expert level and the 9 holes game. Subjects were required to get the ball into the hole of each fairway using the least number of strokes. The smallest number of strokes required to put the ball into the holes of all the fairways in each round of golf would determine the winner.

#### 2.4.2.5 Boxing Game (NWS-Boxing)

There were three rounds in each NWS-Boxing match. In each round, subjects were required to use nun chuck to punch and attack the opponent and to use joystick to move away with a defensive strategy. A point was awarded for each successful punch. The highest number of points collected in each match would determine the winner.

### 3.0 Analyses

The first objective was to identify if there was improvement of cognition among TBI patients by using NWS. To test the outcome of this objective it was necessary to compute  $\delta = MMSE_2 - MMSE_1$ , where  $MMSE_2$  were the readings of MMSE after NWS intervention and  $MMSE_1$  were the readings of MMSE before NWS intervention. The behavior of  $\delta$  in relation to  $MMSE_1$  was used to confirm or repudiate the long held beliefs that some form of VR could improve cognition of TBI patients. The second objective was to determine if the length of time after injury could affect the ability of TBI patients to improve cognition. It would then be necessary to test Hypothesis 1.

Hypothesis 1: Length of time after injury negatively (or positively) affects the ability of TBI patients to improve cognitive functions using NWS.

For this, Kruskal-Wallis Test had to be carried out. The values of Asymp. Sig., Exact Sig. and Point Probability would provide an indicator on the significance of the test. The mean rank of the grouping variable would then furnish information which could confirm whether the length of time after injury negatively or positively or does not affect the ability of TBI patients to improve cognitive functions using NWS. The third objective was to check if GCS mild injury and GCS moderate injury had any effect on the ability of TBI patients to improve cognition using NWS. It would be necessary to test the next hypothesis.

Hypothesis 2: TBI patients with GCS mild injury have significant higher ability to improve cognitive functions using NWS than TBI patients with GCS moderate injury.

To prove this hypothesis it would be necessary to use Mann-Whitney Test. Again, the values of Asymp. Sig., Exact Sig. and Point Probability would provide an indicator on the significance of the test. The mean rank of the grouping variables were used to substantiate the hypothesis. The fourth objective was to see if previous experience using VR had any effect on the ability of TBI patients to improve cognition using NWS. It was therefore necessary to test

Hypothesis 3: VR experience positively affects TBI patients' ability to improve cognitive functions using NWS. To evaluate this hypothesis Mann-Whitney Test was applied.

Kruskal-Wallis Test was used to compare three or more groups while Mann-Whitney Test was appropriate for two groups comparative analysis as the type of data obtained were continuous skewed. Asymp. Sig., Exact Sig. and Point Probability were important parameters. Exact sig. (p value) was an indicator for small number of samples while Asymp sig. (p value) was an indicator for larger number of samples. The condition Exact sig.  $\leq 0.04$  (or Asym. Sig.  $\leq 0.04$ ) meant that if the test decided to reject  $H_0$  (the null hypothesis), it would not wrongly reject the null hypothesis in more than 4% of the cases where  $H_0$  was true. Point Probability was the probability of observing the particular arrangement obtained on the data, given the null hypothesis. The result

from any non-parametric test was significant if Asymp. Sig.< 0.04, Exact Sig.< 0.04 and Point Probability < 0.04 (Pallant, 2001)

#### 4.0 Results

Selection procedure of Fig. 1 resulted in a choice of 30 TBI patients for the experiment. Out of these 30, 76.7% (23) were male and 23.3% (7) were female. The biggest number of subjects that is 60% came from a group 17-35 years old while 26.7% came from an age group 36 years and above. The remaining, that is 13.3%, came from the youngest age group of 16 years. The cause of injury was mainly due to road traffic accident (63.3%). The cause of injury of the remaining 36.7% was due to accidental fall. Detailed information regarding the subjects participating in the experiment is as in Table 2 and Table 3

Table 2:

Characteristics of subjects		
Socio-demographic	Number	%
Male	23	76.7
Female	7	23.3
Below 16 years old	4	13.3
17 – 35 years old	11	60.0
36 years and above	8	26.7
Injury from fall	11	36.7
Injury from road traffic accident	19	63.3
Other minor injury	18	60.0
Moderate to severe injury	12	40.0
Employed	15	50.0
Unemployed	15	50.0
Has history of brain injury	0	00.0
Has no history of brain injury	30	100.0

The graph relationship between  $\delta = MMSE_2 - MMSE_1$  versus  $MMSE_1$  is shown in Fig.3. The relationship has a Pearson Correlation of -0.729 and is significant at the 0.01 level. There is no negative value of  $\delta$  indicating that there had been no decrease in the reading of MMSE after the intervention. Hence for the first objective, the experiment had shown that there is improvement of cognition among TBI patients by using NWS. Those TBI patients whose values of MMSE before intervention were low benefited more from NWS. Using MMSE as the yardstick, experimental results do indicate that TBI patients who were fully recovered did not require NWS to improve their cognitive ability.

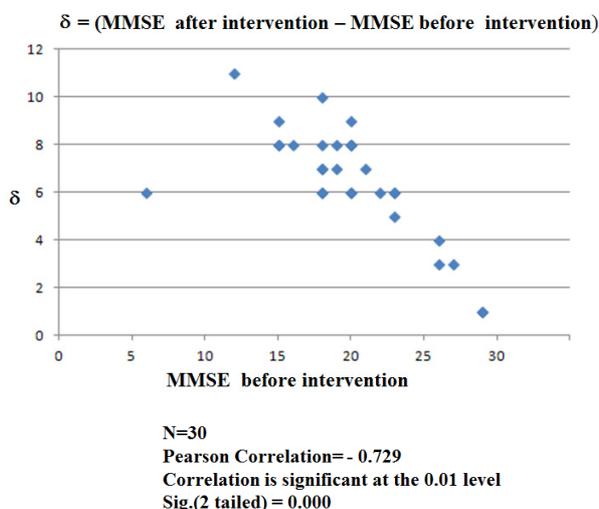


Figure 3. Graph of  $\delta$  vs MMSE before intervention

For Hypothesis 1, Kruskal-Wallis Test resulted in the value of Asymp. Sig. < 0.04, the value of Exact Sig. < 0.04 and the value of Point Probability < 0.04; suggesting that the test was significant and the results were reliable. Let TAI1 = grouping variable for patients less than 6 months after injury, TAI2= grouping variable for patients 7 – 12 months after injury and TAI3=grouping variable for patients more than 13 months after injury. From experimental results, TAI1 had a mean rank of 13.00, TAI2 had a mean rank of 10.33 and TAI3 had a mean rank of 5.17. Rank of TAI1 > Rank of TAI2 > Rank of TAI3. Hence length of time after injury negatively affects the ability of TBI patients to improve cognitive functions using NWS.

For Hypothesis 2, Mann-Whitney Test resulted in the value of Asymp. Sig.> 0.04, the value of Exact Sig.> 0.04 but the value of Point Probability < 0.04; suggests that the test had not produced a significantly well defined result. It was difficult to come to a firm conclusion regarding whether or not TBI patients with GCS mild injury had significant higher ability to improve cognitive functions using NWS than TBI patients with GCS moderate injury.

Many carers had the opinion that TBI patients with experience in playing VR could improve their cognitive abilities more than those without VR experience. Mann-Whitney Test carried out on Hypothesis 3 resulted in the values of Asymp. Sig.> 0.04, Exact Sig. > 0.04 but Point Probability < 0.04. The test had not produced any distinct result to allow confirmation regarding the hypothesis that VR experience positively affects TBI patients' ability to improve cognitive functions using NWS.

For Hypothesis 2 and Hypothesis 3, since Point Probability < 0.04, it did indicate that they could be rechecked by using much bigger samples. Of course, this is wishful thinking. A big number of TBI patient samples will only indicate that Malaysia is not a safe place to live in or that there is a civil war going on.

**Table 3:**  
**Virtual experience & Injury status**

Item	Number	%
With virtual reality experience	17	56.7
Without virtual reality experience	13	43.3
GCS mild	10	33.3
GCS moderate	20	66.7
Less than 6 months after injury	11	53.3
7-12 months after injury	11	36.7
13 months and more after injury	3	10.0

## 5.0 Discussion

The experiment had shown that VR such as NWS do improve the cognitive ability of TBI patients as long as they did not satisfy the Exclusion criteria but conformed to the Inclusion criteria. This had been the views of many occupational therapists and carers since Damásio (Bosse, Jonker, & Treur, 2008 ; Mosca, 2000) defined the connection of cognition which constitutes consciousness, emotion, self-awareness, memory as well as decision-making with the physical body .Certain human occupation could interact and enhance cognitive performance of patients who had suffered from brain impairment (Wirth, et al., 2014 ; Zygmunt, Andersson, & Hogestatt, 2002). In the real-world environment, cognition inherently involves perception and action. The result of this experiment corroborates with the findings of Wilson (Wilson, 2002), Plancher (Plancher, Barra, Orriols, & Piolino, 2012) and Ustinova (Ustinova & Perkins, 2013) who examined the direct link between occupation such as participation in VR activities using specially designed equipment and improvement of cognition of TBI patients.

Brain recovery of TBI patients follow certain well defined patterns determined by the Rancho Los Amigos Levels of Cognitive Functioning (RLCF)(Giacino et al., 2010). Quickest recuperation normally happens in about the first six months after injury. During this time, the injured person will likely show many improvements and may seem to be steadily getting better. TAI1 was the grouping variable consisting of patients whose brain injury had recovered considerably. This explains why TAI1 had the highest mean rank of 13.00. Improvements normally slow down substantially between 13 months and two years. The experimental result for TAI3 was consistent with this phase of recovery. TAI3 was expected to have the lowest mean rank of 5.17. TAI2 was the

grouping variable consisting of TBI patients who were not as badly injured as those in the group variable TAI3 but had not recovered as well as the patients in the group variable TAI1. TAI2 had the mean rank of 10.33. The TBI patients comprising the group variable TAI2 showed some signs of confusion and disorientation with less ability to pay attention and displayed an atmosphere of agitation, nervousness, restlessness and frustration.

### 6.0 Direction on Future Research

The research carried out so far implements intervention techniques using NWS which are digital action games. NWS has the property of activating TBI patients cognitively and physically. NWS is an inexpensive set of digital games which can be bought off the shelf. There is a need to research and design special digital action games to cater for rehabilitation purposes to enhance the cognition of TBI patients who have specific impairments of the brain. It would also be necessary to see if non-action games can improve cognition of TBI patients (Oei & Patterson, 2013). The results of the experiments carried out indicate that there is improvement in cognition of TBI patients when engaged in NWS. However, from the results, it is not possible to predict recovery of cognition functions of TBI patients. It is important to determine parameters which can predict cognition functions recovery of TBI patients after they have been made to undergo a specific intervention experience. This is because a measure which can predict recovery is part of evidential medicine when treating TBI patients (Suzuki, et al., 2013)

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